**Form № 21**

**APPROVED BY**
**JINR Vice Director**

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**SCIENTIFIC AND TECHNICAL JUSTIFICATION FOR OPENING A NEW THEME OR FOR EXTENDING THEME**
**to be included in the**
**TOPICAL PLAN FOR JINR RESEARCH FOR 2022–2023**

**Theme code** 02-1-1097-2010/23 **Laboratory** LHEP

**Department** NEOSFMS

**Research area** Relativistic nuclear physics

**Theme title** Study of Polarization Phenomena and Spin Effects at the JINR Nuclotron-M Facility

**Theme leader** Strokovsky E.A.
**Deputy theme leaders** Piskunov N.M.
Ladygin V.P.
Shindin R.A.

**Abstract**

Polarization studies are undoubtedly relevant now. They combine the efforts of the JINR Laboratories and many foreign laboratories, both participating and non-participating countries, in the design and conduct of experiments using unique beams of polarized deuterons with energies ranging from 5 MeV per nucleon to 5.6 GeV/n, secondary beams of polarized protons and neutrons, as well as beams of polarized protons directly accelerated in the Nuclotron.
The possibility of obtaining beams of accelerated polarized protons in the Nuclotron without significant investment, demonstrated in 2017, became the basis for intensifying work on the spin program of the NICA project and, in particular, for the development of polarimetry techniques, the creation of new methods for precise control of the direction of the spin of protons, deuterons and other particles. This part of the work on the topic is directly related to the creation of the NICA complex and the testing of a new approach to controlling the polarization in the spin transparency mode.
Of undoubted interest is also the study of the possibility of setting up experiments at the collider to measure EDM and parity violation.
The most important scientific and methodological direction of work within the framework of the topic is the development of infrastructure for conducting research with polarized beams, namely: the creation and development of systems for polarimetry and spin direction control. At the forthcoming stage of work, due to the concentration of efforts on the implementation of the NICA project, this component also has the first priority. Within the framework of the theme, two projects are being carried out: ALPOM-2 and DSS. Extension proposals for these projects for 2019-2023. were reported at the STC VBLHEP in April 2021 and approved with a recommendation to assign the first priority to these works.
Taking into account the presence of polarized beams, new experimental data will be obtained on the study of charge-exchange processes, on the study of the structure of 2- and 3-nucleon correlations in the reactions of

deuteron-proton elastic scattering and deuteron breakup (experiments on the internal target of the Nuclotron), by measuring tensor analyzing power and spin correlation in the dp scattering reaction in the deuteron core region, as well as other processes that are important for the development of theoretical models describing the interactions of the simplest nuclear systems with allowance for relativism and the contribution of the meson and quark-gluon components of the internal motion of constituents in nucleons.

**List of activities**

2022-2023 - implementation of DSS and ALPOM-2 projects on polarized beams of deuterons, protons and neutrons.
2022 - the beginning of the design and creation of a part of the equipment for polarization studies at the Nuclotron-NICA complex (first of all, the systems for controlling the beam polarization and polarimetry of the beams of the Nuclotron and the NICA collider).
2022-2023 - development and phased commissioning of modernized systems of experimental installations and diagnostic equipment.

**Results expected upon completion of the theme**

1. Development of infrastructure for spin research at the Nuclotron-M/NICA complex and other facilities. Preparation of technical projects for spin control systems and polarimetry.
2. Investigation of the analyzing power in the scattering of polarized protons (at pulses up to 7.5 GeV/c) and neutrons (at pulses up to 6 GeV/c) on polyethylene, at the ALPOM-2 setup.
3. Study of the structure of 2- and 3-nucleon correlations in the reactions of deuteron-proton elastic scattering and mesonless breakup of the deuteron in experiments on the internal target of the Nuclotron. Measurement of cross-sections and analyzing abilities of these reactions.
4. Preparation of a proposal for the modernization of the Delta-Sigma setup and the Saclay-ANL-JINR proton polarized target (PPM facility) on the polarized neutron channel.
5. Obtaining data on the study of charge-exchange processes in the interaction of polarized deuterons with protons at the STRELA facility.
6. Development of theoretical models for describing the interaction of the simplest nuclear systems taking into account relativization and the contribution of meson and quark-gluon components of internal motion. Theoretical analysis of experimental data obtained at the Nuclotron-M.

**List of projects:**

| | Project | Leader | Priority (period of realisation) |
|---|---|---|---|
| **1.** | **ALPOM-2** | **N.M.Piskunov** | **1 (2018-2023)** |
| **2.** | **DSS** | **V.P. Ladygin<br>K. Sekiguchi<br>M. Janek** | **1 (2010-2023)** |

**List of Activities**

| | Activity or Experiment<br>Laboratory | Leader<br>Responsible person | Leading Researchers and number of participants |
|---|---|---|---|
| **1.** | **Work on the development of infrastructure at the Nuclotron and other complexes for the study of polarization phenomena. Design, creation and development of polarization and polarimetry control systems, consideration of new experiments on polarized beams of the NICA complex** | **A.V. Butenko** | **Realization** |
| | VBLHEP | A.V. Averyanov, V.V. Glagolev, M.Yu. Korobitcina. | |

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|---|---|---|---|
| | | D.O. Krivenkov, R.A. Kuzyakin, M.V. Kulikov, V.P. Ladygin, K.S. Legostaeva, A.N. Livanov, N.M. Piskunov, S.G. Reznikov, R.A. Shindin, E.A. Strokovsky, A.M. Taratin, Yu. N. Filatov, V.V. Fimushkin | |
| | DLNP | Yu. Uzikov, M. Finger, M. Finger (jr) | |
| | LIT | R.V.Polyakova | |
| **2.** | **ALPOM-2 Project** | **N.M. Piskunov**<br>**E. Tomasi-Gustafsson**<br>**C.F. Perdrisat**<br>**V. Punjabi** | **Data taking and analysis**<br>**The setup modernization** |
| | VBLHEP | V.V. Glagolev, I.M. Sitnik, A.A. Povtoreyko, D.A. Kirillov, Yu.P. Bushuev, P.A. Rukoyatkin, O.P. Gavrishchuk, Yu.T. Kiryushin, S.N. Bazylev, R.A. Shindin, A.N. Livanov | |
| **3.** | **DSS Project** | **V.P. Ladygin**<br>**K. Sekiguchi**<br>**M.Janek** | **Data taking and analysis.**<br>**The setup modernization** |
| | VBLHEP | E.V. Chernykh, Yu.V. Gurchin, A.Yu. Isupov, A.N. Khrenov, N.B. Ladygina, A.N. Livanov, S.G. Reznikov, , A.A.Terekhin, A.V. Tishevsky, I.S. Volkov | |
| | DLNP | G.I. Lykasov | |
| **4.** | **DELTA-SIGMA setup** | **R.A. Shindin**<br>**M. Finger (jr)** | **Data analysis,**<br>**Project preparation** |
| | VBLHEP | E.V. Chernykh, I.P. Yudin, Yu.T. Borzunov | |
| | DLNP | N.S. Borisov, Yu.A. Usov, M. Finger, E.I. Bunyatova, M. Slunechka, V. Slunechkova | |
| | FLNP | S.B. Borzakov, Ts. Panteleev | |
| **5.** | **Experiments with the STRELA program on a polarized beam** | **N.M. Piskunov** | **Data taking** |
| | VBLHEP | V.V. Glagolev, Yu.P. Bushuev, A.A. Povtoreyko, D.A. Kirillov,<br>S.N. Bazylev, I.M. Sitnik | |
| **6.** | **Theoretical calculations of polarized processes** | **V.V. Burov**<br>**V.K. Lukyanov** | **Data analysis** |
| | BLTP | V.V. Burov | |
| | VBLHEP | A.P. Ierusalimov, N.B. Ladygina | |

**Participating countries, institutes and organizations**

| Country or Organization | City | Institute or Laboratory | Participants Name, Surname | Status |
|---|---|---|---|---|
| Bulgaria | Sofia | UCTM | | |
| CERN | Geneva | CERN | | |
| Czech Republic | Brno | ISI CAS | | |

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|---|---|---|---|---|
| | Prague | CTU<br>CU | | |
| | Rez | UJV | | |
| France | Saclay | IRFU | | |
| | Orsay | IPN Orsay | | |
| Germany | Bochum | RUB | | |
| | Darmstade | FAIR | | |
| | Dresden | TU Dresden | | |
| | Freiburg | FMF | | |
| | Julich | FZJ | | |
| United Kingdom | Glasgo | U of G | | |
| | | | | |
| Japan | Tokyo | UT | | |
| | Hiroshima | Hiroshima Univ. | | |
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| Poland | Otwock(Swierk) | NCBJ | | |
| Romania | Bucharest | INCDIE ICPE-CA | | |
| Russia | Belgorod | BelSU | | |
| | Gatchina | NRC KI PNPI | | |
| | Moscow | LPI RAS | | |
| | | NRC KI | | |
| | Moscow,Troitsk | INR RAS | | |
| | | LPP LPI RAS | | |
| Slovak Republic | Bratislava | IP SAS | | |
| | Kosice | IEP SAS | | |
| | | UPJS | | |
| | Zilina | UZ | | |
| Sweden | Uppsala | TSL | | |
| Switzerland | Villigen | PSI | | |
| Ukraine | Kharkov | NSC KIPT | | |
| United Kingdom | Glasgo | U of G | | |
| USA | Newport News, VA | JLab | | |
| | Norfolk, VA | NSU | | |
| | Upton, NY | BNL | | |
| | Williamsburg, VA | W&M | | |
| Uzbekistan | Tashkent | Assoc."P.-S." PTI | | |
| | | INP AS RUz | | |

**Total estimated cost of the theme**

| **№№** | **Activities** | **Total cost** | **Costs per years (thousand USD)** | | |
|---|---|---|---|---|---|
| | | | **1st year** | **2nd year** | **3rd year** |
| 1. | Project ALPOM-2 | 40 | 20 | 20 | |
| 2. | Project DSS | 80 | 40 | 40 | |
| 3. | Polarization and polarimetry control systems | 200 | 100 | 100 | |
| | **Total** | 320 | 160 | 160 | |

**Cost estimates for the theme**

| №№ of items | Budget items | Total 2022–2023 | Including 2021 |
|---|---|---|---|
| 5,6 | Materials, equipment | 291 | 97 |
| 18 | R&D work | 129 | 43 |
| 4 | Scientific cooperation | 60 | 20 |
| | **Total** | 480 | 160 |

**AGREED:**

**JINR Chief Scientific Secretary**

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**Head of Planning and Finance Department**

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**Head of Science Organization Department**

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**Laboratory Director**

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**Laboratory Scientific Secretary**

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**Laboratory Economist**

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**Theme leader**

_____ Strokovsky E.A.

"25" May 2021